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# ARCTIC AND SUBARCTIC INSECT PESTS AND THEIR CONTROL

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## INTRODUCTION

In arctic and subarctic regions, the spring thaw is followed by the emergence of mosquitoes, black flies, deer flies, biting midges, and filth-visiting flies in such numbers as to make life nearly unbearable for man and his domestic animals. Although none of these insects is presently concerned with the serious transmission of human diseases in the far north, the biting and annoyance which they cause is so disturbing to morale that they can be considered to constitute a medical problem. Accordingly, successful summer occupation of these regions demands that measures be taken to protect man, and whenever possible to control the insects themselves.

Considerable difference of opinion exists as to the extent of the arctic and subarctic regions and a number of conflicting definitions have been proposed. However, for the purposes of this discussion, the arctic region is conceived to be equivalent to the arctic ice fields and the tundra. The boundary between tundra and forest then becomes the northern limit of the subarctic region (1). The southern boundary of the subarctic is not as easily defined. However, if the presently known distribution of the northern medically-important insects is used as a guide, the subarctic region may be conveniently defined as coinciding with the northern coniferous forests or taiga. The actual limits of these two regions deviate with changes in topography. For example, the subarctic region extends far northward in the basin of the Mackenzie River, and southward extrusions of both regions occur at higher elevations along the ranges of the western cordillera of North America.

Since World War II, there has been a marked increase of studies relating to the greater utilization of the circumpolar areas of the world and within the space of only a decade knowledge of the insect fauna of this great region has been vastly increased (2, 3). Studies on the control of the noxious insect species of the region have been likewise accelerated. However, with all this fund of new knowledge and with all the investigations presently being conducted, lucunae occur in almost every phase of the problem. Consequently, it must be borne in mind that any discussion of northern insect pests and their control will be quickly out of date and will require frequent revision.

A word of caution is in order concerning the control recommendations presented in the following pages. Due to the still insufficient amount of research on the control of arctic and subarctic insect species, it is sometimes necessary to recommend measures proven adequate elsewhere but which have either not been tested or else insufficiently so in the far north. Since control recommendations generally require adaptation to local conditions, it may in some cases be found necessary to vary, modify, or to replace those given below (4).

# I. MOSQUITOES (FAMILY CULICIDAE)

Over most of the land areas of the arctic and subarctic regions, mosquitoes are man's most troublesome summertime problem. On the tundra all the known species of mosquitoes belong to a single genus (Aedes), with the exception that limited numbers of Culiseta mosquitoes may be found where wooded valleys of spruce, willow, and birch intrude into the region of the tundra. To date survey data indicate that mosquitoes do not occur north of the mean July isotherm of $35^{\circ}$ F. (3). In the forested areas the genera Aedes, Culex, Anopheles, and Culiseta comprise the mosquito fauna.

BIOLOGY.

Mosquitoes of the tundra overwinter in the egg stage and have but a single generation each year. Eggs are deposited in the summer on drying surfaces in low areas subject to flooding in the spring. The following spring they hatch as soon as the thaw begins and immersion with water occurs. The immature aquatic stages are completed and the adults emerge approximately four weeks after the mean temperature for 14 days reaches $34^{\circ}$ F. (3). Consequently, for a period of about one month after the thaw the tundra is free of mosquitoes. Emergence of all mosquitoes is completed within a period of two weeks, after which time no aquatic forms can be found until the following spring. Females mate, engorge with blood, and lay their eggs within a few weeks after emergence. For a period of about four weeks after emergence, mosquitoes on the tundra are exceedingly aggressive and beat at one in clouds, getting into mouths, ears, and nostrils, and biting at every opportunity. After this period there is a marked decline in their abundance and aggressiveness which continues until frost begins. At this time, all adults disappear. Culiseta species have a different type of life cycle which is described below.

All of the subarctic species are also single brooded. However, two distinct types of life cycles occur (5). The Aedes species all follow the life cycle described above. However, mosquitoes of the genera Culiseta, Culex, and Anopheles overwinter as fertilized females in sheltered places. With the increasing light of early spring, these females emerge from their resting places to seek a blood meal which is necessary for the development of their eggs. Within two to four weeks after feeding, and when open water surfaces occur, they deposit their eggs in floating rafts (Culiseta and Culex) or singly on the water (Anopheles). Following hatching of the eggs and completion of the larval and pupal stages, a period of a month or somewhat less, the adult mosquitoes emerge. Mating soon occurs and as the summer passes the males gradually disappear. During this first summer the females apparently take no blood, securing necessary energy-producing food as required from the nectar of flowers. Because of the occurrence of these two types of life cycles in the subarctic zone, the mosquito biting season there normally continues for about four months.

The factors affecting adult mosquito activity are of the greatest importance in the development of adequate control measures. Temperature is apparently the most important factor limiting such activity; the optimum range for Aedes species being 55 to $60^{\circ}$ F., the near optimum range extending five degrees above and below this range (6). The lower threshold for activity is 36 to $39^{\circ}$ F., depending on the modifying effects of other meteorological factors such as wind, atmospheric pressure, and the moisture content of the air.

Wind velocity is highly important since in addition to modifying the effect of temperature, it strongly affects the efficiency of the mosquitoes in flight. Winds at velocities of about 12 miles per hour or greater completely prevent attacks on man and at seven miles per hour reduce such attacks by 50 per cent. In other words, mosquitoes are most troublesome on clear, warm days when the wind velocity is less than five miles per hour and when the temperature is between 50 and 65$^{\circ}$ F.

## CONTROL.

Until relatively recently, mosquito control in the arctic and subarctic regions was considered impossible, and the permanent measures, such as draining, filling, and flushing, are still impracticable. However, progress has been made in the development of temporary control measures.

Chemical Control. Due to the fact that all arctic and subarctic mosquito species are single-brooded, it would seem to be possible to obtain effective mosquito control by measures aimed at the destruction of the immature aquatic stages. This is quite true in areas where the flight range of the mosquitoes is limited by forests or other environmental factors. On the tundra, however, where no such limiting factors to mosquito dispersal exist, it has been shown that the blanketing of areas as large as 100 square miles with insecticides may give freedom from mosquito biting for no more than a week's time. Therefore, before attempting the extremely costly and manhour-consuming processes of chemical mosquito control, it is imperative that a thorough knowledge of the local situation be obtained. In general, it is estimated that to give lasting protection to a site, the radius of the control zone should be in the order of the square of the dispersal range of the mosquito species involved (8). From this it can be seen that larviciding measures are generally impracticable in the arctic region, and even in many portions of the subarctic. Adulticiding procedures are helpful if reapplications can be made as required.

With these limitations in mind, the following chemical control measures are recommended. For larviciding, the most convenient method is a prehatching application of DDT to known mosquito breeding places. This can either be accomplished in the autumn before snow, or in the early spring directly to the snow. This method is not more effective than the use of routine posthatching treatments but it has the valuable asset of extending the period during which control measures can be effectively applied. Once hatching occurs, insecticide application must be accomplished in a relatively short period and with the limitations imposed by weather on insecticide application, it is frequently difficult to get all of an area treated in the time available. DDT is the insecticide of choice. For prehatching treatments, an application rate of 0.5 pound per acre is recommended. Posthatching applications should be at the rate of 0.25 pound per acre (local situations may occur which require heavier applications). Oil solutions, water emulsions, or wettable powder suspensions are all suitable for larviciding. However, the latter formulation is superior for prehatching treatments. Oil solutions are less desirable in the arctic because the low temperature of the water prevents proper spreading of the oil film. Also, where valuable vegetation exists, oil solutions may cause damage to plants. The effectiveness of prehatching treatments varies with the terrain. On eroded open terrain, melt and runoff is so rapid that the insecticide is frequently gone before all of the eggs are hatched. Conversely, effectiveness is highest in areas with little or no surface drainage.

Due to the large areas usually requiring treatment and in view of the difficulty attending ground movements, dispersal of larvicides in arctic and subarctic regions is more conveniently accomplished from the air than from the ground.

For adulticiding, space applications of DDT mists or aerosols at the rate of 0.2 pound of DDT per acre is recommended (7). It should be borne in mind that space spraying is a temporary measure only, and that repeated applications will usually be required. Due to the low application rates involved, space sprays normally do not produce an effective

residual deposit of insecticide. Adulticiding space sprays may be applied either from aerial or ground equipment. Suitable ground equipment includes either thermal or mechanical aerosol generators or mist blowers. Vehicles carrying such equipment should be operated at speeds of one to five miles per hour along parallel lines across the area to be treated at right angles to the direction of the wind. Effective swath width varies widely with terrain, meteorological conditions, and equipment, but usually is in the range of 100 to 300 feet. Exterior space spraying should be accomplished when adult mosquitoes are most active and when meteorological conditions are such as to keep the spray low to the ground. In general, aerial application of adulticide sprays is more satisfactory in the north since larger areas can be covered and terrain obstacles are not a limiting factor.

In some areas, the effectiveness of space spraying can be augmented by the application of a "barrier" residual spray to all vegetation surfaces up to a height of 10 feet for a radius of 100 feet from the site to be protected. DDT applied at the rate of five to ten pounds per acre as a water emulsion is recommended for this purpose. All potential mosquito resting and hiding sites should receive treatment.

To insure the most adequate control, it is recommended that all occupied interiors also be treated with space and residual sprays. Interior residual treatments should be made with five per cent DDT, either as an emulsion, solution, or suspension, applied to all surfaces on which mosquitoes are likely to rest. The rate of application should be sufficient to wet the surface but not put on to the point of run-off. Cylindrical sprayers (1-3 gallon capacity) equipped with a fan-type nozzle are excellent for this purpose. Continuous pressure hand sprayers (2-quart capacity) can also be used. Nozzles giving a coarse wet spray are required. While spraying, the nozzle should be held 15 to 18 inches from the surface being sprayed. To avoid the production of many very fine droplets, air pressure in the sprayer should not exceed 40 pounds per square inch. Interior space spraying is accomplished most conveniently by the use of aerosol bombs. However, small hand or electrical sprayers equipped with nozzles capable of producing very fine droplets may also be used and have the advantage of being refillable. For an insecticide formulation for this purpose, DDT at a concentration of one to three per cent with a quick knockdown agent added, such as pyrethrum, allethrin, or one of the thiocyanates, is recommended. Aerosol treatments should be at the rate of seven seconds of discharge per 1000 cubic feet of space. Application rates for space sprays applied with sprayers must be determined by observation. As a rule, the efficiency of space-spray treatments is improved by closing the treated space for a period of at least 15 minutes following application.

Personal Protection. In many portions of the arctic and subarctic regions, the successful accomplishment of summertime outside activities requires an extensive use of such personal protective measures as the wearing of special clothing and the use of repellents and smudge fires.

Clothing. Adequate protection for most of the body can be obtained by a careful selection of clothing. Since mosquitoes prefer to bite on exposed areas, the first requirement is to cover as much of the skin as is feasible. And since they will also bite freely through clothing, the second requirement is to select cloth that prevents the occurrence of such an event. Tightly woven fabrics, maximum allowable aperture between threads is 0.08 mm. (8), are available, but since such fabrics tend to be disagreeably hot, it has been suggested that an open fabric held away from the skin by a partial or complete lining of netting or other material with sufficient thickness to prevent the proboscis of the mosquito from reaching the skin would be more comfortable. For example, a string vest worn under a cotton shirt has been found to give complete protection and is furthermore cool and comfortable in the warmest weather. In all cases, protection can be increased by impregnating the clothing with repellents. To increase the effectiveness of the clothing barrier, zippered closures should be used and trouser bottoms should be tucked into the tops of the socks. The sleeve cuffs of the outer garment should be tightly fitted. Also, since it has been amply proven that more mosquitoes will land on dark colored materials than on light,

it is recommended by some that white or khaki colored fabrics be selected. The effectiveness of this procedure is, however, somewhat negated by the discovery that when unattractive colors are worn the landing rates of mosquitoes on exposed skin areas increase. Nonetheless, by the judicious selection and wearing of clothing, it can be seen that all but the hands and face can be protected sufficiently to prevent mosquito biting. These remaining exposed areas can be protected either by wearing head nets and gloves with gauntlets or by using an insect repellent.

When head nets are used, they should stand out from the face so that they do not touch the skin. Conventional head nets are worn over a hat with a brim. These are sewed directly to the crown of the hat or attached with an elastic band that fits snugly to the crown. At the bottom there should be a strip of strong cloth encasing a drawstring for tying snugly at the collar. With a broad coil of lightweight flat steel wire fastened on the inside, the net will stand out from the face, and at the same time can be packed flat. Cloth nets should be made of the best grade of fine-meshed bobbinet, should have at least 18 meshes to the inch, and should be dyed black for improvement of visibility. Head nets can also be made of wire screen with cloth and drawstring at the bottom. However, at best a head net definitely impairs vision, offers a considerable obstacle to such activities as eating and smoking, and presents a serious problem when traveling through bush. A form of protection for the head which is nearly as effective as a head net against mosquitoes can be made from a cotton cloth hat with a three inch brim all around by attaching a shoulder length fringe of strings to the brim with the exception of a space of five inches in the front (8). The strings should be of cotton, 10 inches long and one-fourth inch apart. If desired, the fringe may be extended across the front down to eye level, or even full length, vision still being better than through a conventional net. Treatment of the fringe and hat with repellent offers still more protection.

Gloves also are necessary when mosquitoes are really numerous. Kid gloves with a six-inch cloth gauntlet closing the gap at the wrist and ending with an elastic closure are preferred. Cotton work gloves are better than no protection at all, but mosquitoes can bite through them. However, treating the gloves with insect repellent will increase the protection. For delicate work, kid gloves with the fingers cut off offer some protection. In this case, use of insect repellent on the fingers is suggested.

Bed Nets. Field operations in the north may require sleeping out at night without the protection of a tent or other type of insect proof shelter. In such cases, the use of bed nets or fly bars is essential. It has been shown that the standard cheesecloth bed net available commercially is generally unsatisfactory because it is complicated to erect and the cheesecloth stretches and is easily snagged (10). Experimental work by the Defense Research Northern Laboratory, Canada, has resulted in a suitable product for this purpose. It consists of a cylinder made of 24 mesh Saran plastic screening which is pulled over the head of the user and fitted tightly around the waist. A hoop holds the screening away from the head. This net requires no staking to the ground and it permits the user to roll about in his sleep with perfect protection.

Repellents. The use of repellents in combination with protective clothing will insure a high degree of human comfort in most northern situations. They may be applied to the clothing, directly to the skin, or preferably to both. For use on skin, repellents must be evenly and thoroughly spread over all exposed skin surfaces. About 12 drops should be shaken into one hand, the hands rubbed together and the repellent applied in a thin layer to the face, neck, ears, hands, and wrists. Care should be taken to prevent the material from getting into the eyes or on the lips. The newer repellents are all solvents of paints, varnishes, and plastics and should be kept from contact with such materials, including nylon. The application of repellents to the outside of the clothing, especially across the shoulders, around the waist and on the seat of the trousers has definite protective value. They can be applied to clothing by hand or with a sprayer. Impregnation of clothing with repellent through dipping procedures is a particularly valuable technique where military

forces are involved. The most satisfactory repellents commercially available are 6-2-2 (a mixture of dimethyl phthalate, Rutgers 612, and Indalone), a 7:3 mixture of 2-phenyl cyclohexanol and 2-cyclohexyl cyclohexanol, and M-2020 (a mixture of dimethyl phthalate, 2-ethyl hexanediol-1, 3, and dimethyl carbate). The compound diethyltoluamide has been found to be even more superior as a skin repellent than those listed above and will undoubtedly be commercially available at an early date. Repellents, when properly applied should give protection for two hours or more under most conditions. However, with a heavy and aggressive population of mosquitoes, and with the perspiration resulting from the activity of an individual at work, the best of repellents may require reapplication at shorter intervals.

Smudge Fires. Certainly not an unimportant protective measure available to an individual in the field, is the use of smudge fires. Built in a pail or pot, a bucket smudge is very useful since it can be moved if the wind shifts or can be taken inside a tent until all mosquitoes are driven out. Two inches of sand or soil should be placed in the bottom of the bucket before the fire is started. The smudge is obtained by adding green vegetation, moss, damp leaf mold, or rotten wood to a strong wood fire.

Protection of Quarters. The mosquito problem in the arctic and subarctic can be reduced by locating quarters on wind-swept ridges near the coast, or in widely cleared areas in timberlands. However, even then, complete protection will normally be obtained only by the mosquito-proofing of inhabited buildings. To accomplish this all openings, including ventilators, drainpipes, and sometimes chimneys, should be screened with suitable mesh wire or plastic screening. Standard 18-mesh screen with a wire diameter of 0.009 to 0.010 inch and meshes 0.0456 inch across, will exclude mosquitoes. Screen doors should open outward. Wherever possible, it is preferable to use double doors and then occasionally spray the confined space between them with an insecticide. Self-closing devices on all entrance doors are useful. The entrance to tents can be screened by the addition of a bobbinet curtain weighted with shot or of a solid bobbinet panel pierced by a circular opening which can be closed with a drawstring. Further protection is afforded by the addition of a complete floor or of cloth extensions, approximately 12 inches wide, extending inwardly from each wall and anchored to the ground. Temporary structures for the camp work and latrine areas can be readily and cheaply constructed with cheesecloth and staples and will be of immeasurable help in maintaining good morale. When quarters become invaded by mosquitoes, aerosols or sprays should be used as recommended earlier.

Treatment of Bites. The itching and pain suffered by some individuals from mosquito bites usually can be alleviated by the use of one of the following mixtures:

| | | | |
|---|---|---|---|
| a. | (9) | n-butyl-p-aminobenzoate ("Butesin") | 100 gm. |
| | | benzyl alcohol | 170 cc. |
| | | anhydrous lanolin (malted) | 22 cc. |
| | | cornstarch | 640 gm. |
| | | sodium lauryl sulfonate | 64 gm. |
| | | (Apply in a moderately thick layer to skin moistened slightly with water.) | |
| b. | (8) | benzocaine | 10 % |
| | | salicylic acid | 5 % |
| | | methyl salicylate | 2 % |
| | | isopropyl alcohol | 83 % |

If these formulations are not available, cold wet compresses made with baking soda or weak ammonia water will offer some relief.

# II. BLACK FLIES (FAMILY SIMULIIDAE)

Various species of Simulium, Prosimulium, and Cnephia, commonly known as black flies or buffalo gnats, occur in enormous swarms in the arctic and subarctic, where they cause great annoyance to man and his domestic animals. Black flies are small, dark, stout-bodied humpbacked flies with short, broad wings and short legs. Although not known to be involved in disease transmission in the north, the biting of black flies has resulted in the death of livestock, and their bites on humans often result in swellings and hard lesions that may remain sore and itchy for days (11). Nearly as important is the psychological trauma caused by the habit peculiar to several species, of flying closely about the face and of crawling and probing over all exposed skin surfaces.

## BIOLOGY.

As with mosquitoes, black flies pass through four stages of development: egg, larva, pupa, and adult. Immature forms of black flies develop in running water. Usually, eggs are deposited in masses on aquatic plants, logs, and water-splashed rocks. However, some species lay their eggs while flying over the water surface where they sink to the bottom. Following an incubation period, the eggs hatch and the new larvae attach themselves by means of silken threads to submerged rocks and logs. Larvae feed on organic particles strained from the water and swept into the mouth by a pair of fanlike mouth brushes. They breathe by obtaining oxygen from the water through three small gills at the tail end and through the skin of the body. Before pupating, the larva spins a cocoon which is firmly attached to objects in the water. The larva then transforms to a pupa within the cocoon. The pupa breathes through two tufts of respiratory filaments that project from the front end of the body. The length of the aquatic life stages varies from two to many weeks depending upon the species, temperature, availability of food, and other environmental factors. Transformation to the adult takes place within the cocoon. Upon emerging and rising to the surface the fly takes wing immediately. Depending on the species and the geographical location, there may be one to four generations a season. Where more than one generation occurs, they overlap so that for at least one period during the summer all of the stages may be found simultaneously. Over-wintering occurs in the egg stage in some species and in the larval stage in others.

Like mosquitoes, black flies feed on the nectar of flowers. The females also feed on the blood of wild and domestic animals and birds, and several species regularly feed on man. The males do not bite. A number of discrepancies are to be found in the literature about the man-attacking habits of black fly species, some being reported to bite man freely in one area and not in another. A seasonal variation also occurs in this respect. Actually, in the north only very few species of black flies are serious biters of man. However, several others cause severe annoyance to man by their habit of flying about the face and of crawling or probing over all exposed skin surfaces. The reason for this type of habit is not clearly understood. Little precise information is available on the distances over which black flies normally disperse. In general, however, prairie and tundra species are capable of dispersing many miles whereas forest species have relatively restricted ranges.

## CONTROL.

Black flies are most effectively controlled by the application of larvicides to the streams where the immature forms are developing. Where only one brood of black flies emerges annually, a single treatment of streams should markedly reduce the pest problem. More frequent treatments are necessary when two or more generations emerge in a season. It is recommended that larviciding be accomplished with a five per cent solution of DDT in fuel oil applied at the rate of 0.15 to 0.25 parts of active ingredient per million parts of water for 30 minutes at the point of application. This dosage will not seriously affect other aquatic life but over-dosing must be guarded against since 10 parts per million of DDT will kill fish. Also, emulsions should not be used because of their higher toxicity

to fish. To be effective, a black fly larviciding program in wooded areas should include all infested streams within a five mile radius. The larvicide should be applied at points as far upstream as can be reached and preferably in turbulent water to insure adequate mixing. One treatment is sufficient to eliminate larvae for a distance of at least two miles downstream. The number of pints of a five per cent DDT solution required for an application can be calculated from the formula $\frac{V \times W \times D}{9}$, where V = average velocity in feet per second, W = width in feet, and D = average depth in feet (12). Treated streams should receive a preliminary inspection 24 hours following treatment and then be regularly reinspected at two- or three-week intervals thereafter. DDT larviciding can also be accomplished by aircraft. In this case, apply the spray by flying the length of the stream emitting the spray at intervals, or where several streams are involved by flying parallel swaths across the area at quarter-mile intervals. Application should be at the rate of approximately 0.2 pound of DDT per acre. Although not too effective, space applications of DDT against black fly adults can be employed. Treatments should be as described for mosquitoes except that it is recommended that aerial applications be at the rate of 0.25 pound of DDT per acre.

Although the biting rates of black flies are usually much lower than those of mosquitoes, personal protective measures against them are just as essential. Due to the larger size of their biting punctures, in which an anticoagulin is secreted, black fly bites usually bleed and, as pointed out above, frequently produce painful lesions. In general, all of the measures described earlier for protection of the individual and his quarters from mosquito biting apply equally to black flies. Since black flies characteristically crawl beneath clothing whenever the opportunity presents, it is very essential in preventing their bites to insure tight fitting cuffs and collars. Also, due to their smaller size, protective screening, netting, and fabric must have a minimum of 20 meshes to the inch and 28 S.W.G. wire or fiber (8).

# III. BITING MIDGES (FAMILY HELEIDAE)

A few species of Culicoides, variously known as punkies, no-see-ums, or mooseflies, occur in the subarctic region. These blood-sucking midges are extremely small in size, and meshes capable of holding out mosquitoes are readily penetrated by them. Although not known to be disease vectors in the north, they can be very troublesome pests to man and his domestic animals. Some individuals experience rather marked reactions to their bites, although not in the same order of severity resulting from black fly bites.

## BIOLOGY.

Little is known as to the biology of these species in the subarctic. However, the biology of one of the species occurring at the southern limits of this region has been worked out in southern Alaska (13), and it is probable that the details hold in general for species occurring further north. Culicoides tristriatulus, a severe biting species in the coastal areas of Alaska, passes its immature stages in vegetation-covered muck and soil in areas subject to inundation by the high tides and by the flooding of the coastal rivers. The eggs are presumably laid directly on the soil in these areas and hatch when flooded. The new larvae penetrate into the muck for a distance of an inch or less where they complete their larval development. The winter is passed in the larval stage in the soil. Pupation occurs in the spring. A short time before the adults are ready to emerge, the pupae work their way to the surface and when the area is flooded may be found floating on the water. Upon emerging, the adults take wing very quickly. As with mosquitoes and black flies, only the female bites, but it is believed that the adults of both sexes feed on the nectar of flowers. Very little is known on the dispersal ability of the northern biting midges, but adults of C. tristriatulus have been found more than four miles from all known breeding areas and are presumed to have dispersed there as adults, although it is possible that dispersal by floating pupae may have accounted for this extensive distribution.

CONTROL.

Many insects are most effectively controlled in the immature stages since at that time they are usually rather definitely grouped. This would apply equally well to Culicoides except for the fact that it is quite difficult to determine where breeding is occurring, and even the limits of the area involved because of their habit of developing in the soil. In addition, the larvae are very small. Careful survey work with soil flotation methods will demonstrate the presence of Culicoides larvae but the procedure is tedious and even in the hands of experts subject to a considerable amount of error. Nonetheless, any serious attempt to effect control of human biting species of Culicoides must be preceded by an extensive and careful larval survey. Where the areas supporting larval breeding can be determined, it has been demonstrated by the U. S. Department of Agriculture that control of larval Culicoides can be obtained by the application of insecticides directly to the soil (for example, granulated dieldrin applied at the rate of 1.25 pounds of actual dieldrin per acre). However, this is expensive since control must be done on an area basis if early entry by midges from surrounding uncontrolled areas is to be avoided. Space applications of DDT against the adults as described for black flies and mosquitoes are probably the most effective control measures presently available for bringing some measure of relief for small population groups.

Personal and quarters protective measures recommended against mosquitoes are all equally effective against Culicoides. However, the extremely small size of Culicoides must be kept in mind wherever meshed screens or fabrics are to be used. It has been demonstrated (8) that, in order to exclude Culicoides midges, 40 mesh screening of 34 S.W.G. wire is required.

# IV. HORSE AND DEER FLIES (FAMILY TABANIDAE)

The small deer flies of the genus Chrysops and the massive horse flies of the genus Tabanus are numerous in parts of the arctic regions, but they are not serious human pests there. In certain subarctic areas, however, they can be the source of considerable discomfort to man and his domestic animals. Female flies silently inflict a painful bite and the large puncture may bleed for some time after the fly has completed its blood meal.

BIOLOGY.

The larval life of these flies is passed in the water or in wet soil. Eggs are glued in layers or masses, to rocks or vegetation overhanging water or damp soil. The egg stage is short, usually less than two weeks. Upon hatching, the larvae drop into the water or onto the moist ground. Larvae are usually predaceous and require at least one and, most usually, two or three years to complete development. Mature larvae migrate to drier soil for pupation, where after a week or two the adult flies emerge. Overwintering in the north is in the larval stage (14).

CONTROL.

Little help can yet be given on the control of these pests. Space applications of insecticides similar to those recommended for mosquito control may be effective under some conditions, particularly if applied when the adult flies are active. However, in areas of heavy populations of Tabanus and Chrysops, the use of adulticides has not proven to be really satisfactory. The use of larvicides has the same drawbacks as described for the larval control of Culicoides.

The personal protective measures described previously will serve equally well for protection against these flies, except that present repellents are not as successful as could be desired. Horse and deer flies will freely enter quarters but not for biting purposes; consequently, the protection of quarters is not a problem here.

# V. SNIPE FLIES (FAMILY RHAGIONIDAE)

Snipe flies are not commonly known because of their limited distribution. Aggressive in nature, they inflict bites silently and suddenly on exposed portions of the body. Nothing is known of the breeding habits or life history of these pests, except that their predaceous larvae breed in moist soil. Consequently, until more biological data is available, control measures cannot be established.

# VI. FILTH FLIES (FAMILIES CALLIPHORIDAE AND SARCOPHAGIDAE)

The large metallic blue-bottle flies (Calliphoridae) and the equally distinctive gray and black flesh flies (Sarcophagidae) are considered together because of their breeding habits. Adults of both groups visit filth and their larvae (maggots) develop in carrion and animal excrement. In the arctic, overwintering apparently occurs in either the egg or early larval stages of development. Adults appear four to six weeks after the thaw. Although they tend to swarm near the breeding places, they can travel several miles in search of food. In subarctic areas these and several other forms of blow flies and flesh flies with similar habits are abundant.

Prevention of fly breeding is the simplest and most effective manner of controlling filth flies (15). Sanitary disposal of garbage and human excreta is not always possible in the arctic. Mere removal of these wastes from the camp area is not sufficient, and burial of the materials is impractical because of the permafrost. If camp is located near swiftly running water, wastes may be emptied there. When stored during the winter months, wastes should be dumped as soon as the thaw permits. If such disposal is impractical, sanitary wastes should be removed from the camp area and sprayed heavily with a five per cent solution of DDT in kerosene or fuel oil. Drums used to transport garbage and excrement must be cleaned by washing or by burning at frequent intervals. Latrines, particularly attractive to flies, should be treated with a residual spraying of a five per cent solution of DDT in kerosene. One treatment will suffice for the entire season. The practice of urinating or defecating in the snow near quarters during the winter may be convenient, but it will produce swarms of flies in the spring. Food, especially meats, should be stored in screened, flyproof containers to prevent contamination by the flies.

Measures described for the protection of quarters against the entrance of mosquitoes will serve equally well against these flies.

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